THE TEACHING OF CHEMISTRY IN THE SECONDARY SCHOOLS: A STUDY OF RECENT PRACTICE AND RESULTS[1]

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I. INTRODUCTION

During the last few years there have appeared in the educational periodicals a number of articles on the course in chemistry which should be given in the secondary schools. Committees have reported and many methods of teaching have been suggested. These outlines set, let us say, the standards or the ideals of the teachers. It is interesting now to observe in a comparative manner the prevailing practice and the results.

In the fall of 1904 it was my pleasure to read the chemistry notebooks which were presented for entrance to Cornell University, as part of the necessary credentials, by those who entered without examination. Accompanying each notebook was a card upon which were written certain facts about the course pursued by the student. These facts gave data showing the nature and extent of the course. The study of these books and data was the best possible way, short of an actual visitation, to learn the methods and results of secondary-school work. Here were the credentials which the teachers and students were willing to have reviewed as evidence of the quality and quantity of their work. Yet it was not specially done, as for an exposition, but represented the honest, faithful daily work of both student and teacher under ordinary conditions. The data gathered in 1904 were amplified by those from the credentials of 1905, the whole classified and rearranged, and this paper written after the two years' investigation.

No attempt was made to arrange the subject-matter presented, for that was more or less common to all the courses. The time spent on the laboratory work, the character of the record of the

[1]A paper read at the tenth annual meeting of the New York State Science Teachers' Association, December 28, 1905.

experiments, the habits of thought of the students, and the quantitative experiments showed such remarkable diversity that these topics were made the important considerations in the classification.

This paper will include, therefore, first, a study of the time spent in laboratory work, recitations, and lectures; second, the different methods of recording the results of the experiments; third, the literary character of the record; fourth, the scientific character of the record; fifth, the results of certain special features of the course, viz., the quantitative experiments; sixth, some observations and suggestions. Photographs of pages of notebooks are used as illustrations, although in no case is the name of any school divulged.

The schools from which notebooks were received may be classified as follows: (1) schools in New York state—public schools, 83; private schools, 23; total, 106; (2) schools outside New York state—public schools, 76; private schools, 31; total, 107; grand total, 213. The total number of notebooks read was 485.

II. TIME SPENT ON CHEMISTRY

Perhaps the best starting-point in this discussion is a consideration of the amount of time spent in the study of chemistry. In general, three standards may influence the teachers of New York state. First, the report of the Committee of Nine,[1] in which it is stated that the laboratory work should comprise at least 108 hours all told, divided into periods of 1½ hours each and two periods per week; the recitations should occupy two 45-minute periods per week; and the instructor should give one experimental lecture per week.

The second standard is that of the New York State Education Department. In the syllabus of 1900,[2] which prevailed at the time the notebooks here reviewed were written, there is given no definition of the number of hours to be spent in recitation or laboratory. Therefore the work was done under no time limitation. For the sake of comparison with the other standards, it may be mentioned in this connection that in the syllabus of 1905[3] the department

[1] University of the state of New York, *High School Bulletin No. 7*, (1900) p. 714.

[2] *High School Bulletin No.* 8, (1900) p. 117.

[3] New York State Education Department, *Secondary Education, Bulletin No. 27*, (1905) p. 82.

expects of its teachers "laboratory work consisting of exercises requiring 30 double periods of work." This reduces to 45 hours all told, divided into periods of 1½ hours each, and one such period per week. Classroom work and experimental lectures are required, although no number is mentioned.

The third standard is that of the College Entrance Examination Board.[1] This board is general in its statements, but places the lower limit of laboratory work at 40 exercises. There is no numerical definition of the word "exercise." From a study of the 60 exercises listed it is evident that at least 1½ hours are necessary for each. The minimum requirement of the board may then be assumed to comprise 65 hours all told, divided into periods of 1½ hours each, and a few more than one per week.

There can be no doubt that other standards exist, for each college interprets these requirements according to its own ideas. Several of the colleges and universities demand of their entering students a preparation entirely independent of the standards named. No attempt is made to classify the other standards, since they vary but slightly from those mentioned.

Table I shows in what percentage of the schools the work was done in the more common divisions of time. The data are arranged by public and private schools, as the natural and most interesting classification, and since in New York state the private schools probably show the influence of the College Entrance Examination Board, while the public schools are more apt to show the influence of the State Education Department, or the Committee of Nine of the State Teachers' Association. From the tendency of the public schools toward the shorter hours, and the private schools toward the longer, it would seem that these boards have had their influence, although this influence has not been of exceptional moment.

In spite of the emphasis which, during the last five years, has been laid upon a laboratory period of 1½ hours in length, 36.7 per cent. of the public schools of New York state still conduct their laboratory work in 45-minute periods, while only 30.4 per cent. use the double period. In the public schools outside the state the situation is practically the same.

[1] *Document No.* 20, (1904) p. 29.

TABLE I

TIME SPENT IN LABORATORY WORK

Hours in Each Laboratory Exercise	Percentage of Schools					
	Schools in New York State			Schools outside New York State		
	Public	Private	Total	Public	Private	Total
¾	36.7	18.2	32.7	31.6	6.9	24.8
1	22.8	27.3	23.8	15.8	17.2	16.2
1½	30.4	22.7	28.7	26.3	37.9	29.5
2	8.8	31.8	13.8	23.7	34.5	26.7
3	1.3	0.0	1.0	2.6	3.5	2.8
Laboratory Exercises per Week						
1	14.1	18.2	15.0	13.2	20.6	15.2
2	37.2	36.4	37.0	32.9	27.6	31.4
3	23.0	31.8	25.0	32.9	27.6	31.4
4	12.8	9.1	12.0	11.8	6.9	10.5
5	10.2	4.5	9.0	9.2	17.3	11.5
6	2.7	0.0	2.0	0.0	0.0	0.0
Total Hours						
0–50	8.9	9.1	8.9	2.6	10.3	4.8
51–80	24.0	22.8	23.8	21.1	10.3	18.1
81–100	21.5	4.5	17.8	22.4	10.3	19.0
101–120	19.0	36.4	22.8	22.4	10.3	19.0
121–150	6.3	13.6	7.9	14.5	27.6	18.1
151–300	20.3	13.6	18.8	17.0	31.2	21.0

Less than the double period (1½ hours) is used in New York state by 59.5 per cent. of the public schools, 45.5 per cent. of the private schools, and 56.5 per cent. of all the schools in the state. In the schools outside of New York state the figures are still large; for of the public schools 47.4, of the private schools 24.1, and of all the schools 41.0 per cent. use less than the double period.

Nevertheless, excepting test tube experiments, the period of 1½ hours is none too long for a student to set up the apparatus for such experiments as the quantitative experiments, the preparation of the acids, etc., perform the work thoughtfully, write even the roughest of notes, and take down and put away the apparatus. The majority of exercises outlined by the above-mentioned boards cannot satisfactorily be performed in less than that time. Perhaps some will say that they are using the short period with favorable results.

Evidently many are gaining a species of result, for the number of schools in which this period is used is large; but to do even passable work the boys and girls are driven at such an intense pace that their thinking ability can only be slightly developed. The work in chemical laboratories is conducive to habits of quiet study. Things do not go rapidly. Attempts to rush are usually disastrous. One does not observe off-hand why oxygen is evolved from potassium chlorate. A little thoughtfulness, at least, is necessary. But when excessive speed is demanded, it becomes easy to form the habit of superficial thinking, which is one of the most common and most reprehensible habits which can be formed by the student of chemistry. It then is so easy for him to regard his chemical work as the mere mixing of so much "stuff," with a conesquent play of colors, or an explosion.

It is noticeable that the shorter periods are found among the public schools of New York state more than among any of the other classes named.

The double period is found in New York state in 30.4 per cent. of the public schools, 22.7 per cent. of the private schools, and 28.7 per cent. all told. Outside New York state the figures are not much different, except with the private schools, among which this period is employed by 37.9 per cent. The longer periods are found more frequently among the private schools than the public schools, 31.8 and 34.7 per cent., respectively, finding place for the 2-hour period.

In the second part of Table I it is seen that the majority of schools favor either two or three laboratory periods per week. In some schools there is only one period, and in a very few as many as five or six periods. Two periods per week would seem to be sufficient to give all desired results.

There is even greater diversity in the total number of hours spent in the laboratory. If 100 hours be taken as the dividing line, then in New York state 54.4 per cent. of the public schools spend less than that number of hours on the laboratory work. Outside New York state 46.1 per cent. spend less than 100 hours in the laboratory. Among the private schools the figures are 36.4 and 30.9 per cent., respectively. More time is spent on the work, therefore, outside of New York state than in New York state. Judged accord-

ing to the standard of the Committee of Nine (108 hours), the above figures give the fraction of the schools which do not attain to that standard.

The hours from 151 to 300 may be excluded, on the ground that that amount of time is unreasonable, or not comparable with the standards mentioned. The most rational hours are between 101 and 150, which are found in New York state in 25.3 per cent. of the public schools, 50.0 per cent. of the private schools, and 30.7 per cent. all told; and oustide New York state in 36.9 per cent. of the public, 37.9 per cent. of the private, and 37.1 per cent. of all the schools. These schools meet the standard of the Committee of Nine and exceed that of the College Entrance Examination Board.

Judged by the standard of the New York State Education Department, the public schools of this state more than meet the requirements, since all but 8.9 per cent. show more than 50 hours devoted to the laboratory work. The syllabus, if it be correctly interpreted, sets a minimum standard. To accomplish satisfactory results in a laboratory course is a different question. As already mentioned, this minimum seems altogether too low. No student can derive a suitable training, nor gain a reasonable knowledge of the experimental part of the subject, in 45 hours of laboratory work.

The College Entrance Examination Board and the Committee of Nine recommend a number of experimental lectures to illustrate laws and phenomena, which demand the greater experience of the instructor for their successful demonstration. In Table II it may be observed that in the New York state public schools, to the extent of 58.2 per cent., no such lecture is given; 17.7 per cent. show from 26 to 40 lectures, or about one per week. In the private schools 22.8 per cent. show more than one per week. In 54.4 per cent. of the schools outside New York state no lecture is given. These data may be in error to a certain degree, for some of the teachers may have misunderstood the question. However, it can, at least, be stated that not over 23.7 per cent. of the schools in New York state, and 24.6 per cent. of the schools outside New York state, give experimental lectures as often as once a week, while the lecture side of the course, in 54.5 and 54.4 per cent., respectively, was not of sufficient moment to make any serious impression upon the teacher.

TABLE II

TIME SPENT IN CLASSROOM

Experimental Lectures	Percentage of Schools					
	Schools in New York State			Schools outside New York State		
	Public	Private	Total	Public	Private	Total
0	58.2	40.9	54.5	52.6	58.7	54.4
1–10	11.4	4.5	9.9	9.2	13.8	10.5
11–25	10.1	18.2	11.9	10.3	10.3	10.5
26–40	17.7	13.6	16.8	19.7	6.9	16.2
41–90	2.6	22.8	6.9	8.0	10.3	8.4
Recitations per Week						
1	1.3	4.5	2.0	10.5	13.8	11.4
2	10.1	22.7	12.9	31.6	20.6	28.6
3	36.9	22.7	33.8	25.0	34.5	27.6
4	17.7	27.3	19.8	13.2	17.2	14.3
5	34.0	22.8	31.5	19.7	13.9	18.1

Evidently the experimental lecture is not popular. The full explanation is not obvious, although several reasons may be assigned. A considerable equipment is needed for lecture experimentation, and this equipment is expensive. Then, again, the teacher's time is pretty fully engaged with routine work, and he is allowed little or no opportunity for the preparation of lectures. It takes time to successfully prepare the apparatus for an experimental lecture, as all who attempt to give such lectures are well aware. Yet this is a fact which is not generally appreciated by the school officers, for many an otherwise ambitious teacher is prevented from developing his course, because he is required to be on duty in classroom or study-hall, when his value to the school would be better conserved if that time were spent in preparing lectures or arranging the laboratory.

In connection with the study of the data on the experimental lecture, it is interesting to notice that where the lecture is weak the recitation is strong. In 34 per cent. of the public schools in New York state there are 5 recitations per week; over 3 per week in 51.7 per cent.; and 3 recitations in 36.9 per cent. In all but 11.4 per cent. there are over 2 per week. The data from the private

schools and from those outside New York state seem to favor few recitations and incline toward 2 and 3 per week.

So far as the notebooks presented by the students from the schools classified above are concerned, it may be stated that in general those from the schools in which the longer laboratory hours prevail show the best results. There are exceptions, but the shorter hours seem to prevent good work.

III. THE METHOD OF RECORDING THE EXPERIMENT

The methods of recording the experiment fall generally into four classes.

In many schools the printed manual is used, and, as Fig. 1 shows, the student is allowed to write his record on the page opposite the

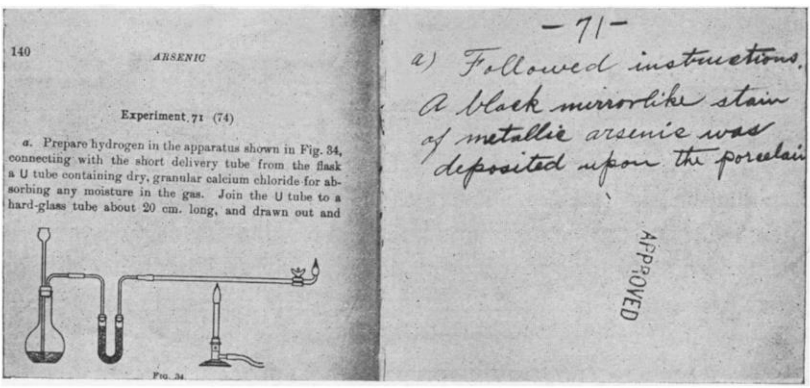


FIG. 1

directions. The difficulty arises from the ease with which the student forms the habit of writing up the work after the manner just shown. Little benefit was derived in this case. Yet with care in its use it is possible to gain desirable results with the printed manual. The book itself, in whatever way it may happen to be printed, is not of moment. But when the only record consists of perfunctory answers to a few questions, the results are unquestionably bad.

The second method of writing up the notebook is illustrated by Fig. 2. In this form of record, which may be called the tabulated form, the various headings under which the student is supposed

to write the details of the experiment and conclusions are written or printed on the page. Such a plan reduces the work of the student

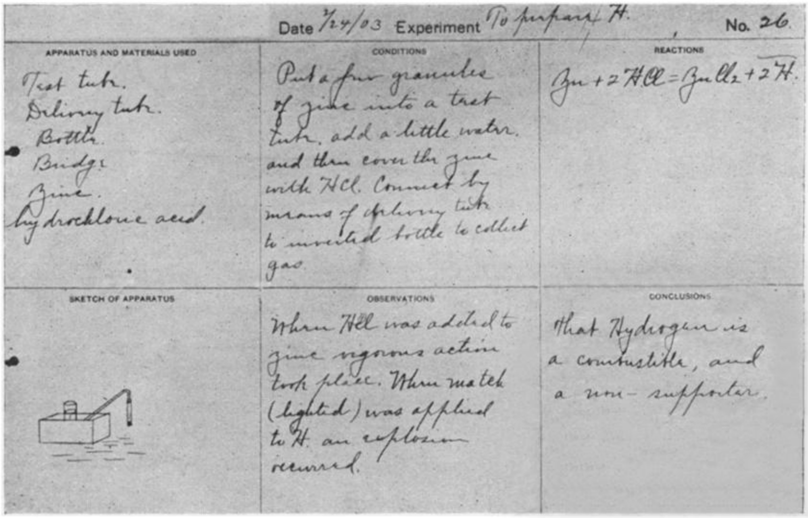


FIG. 2

to the minimum, he has only to fill in the blank spaces. The plan is pernicious, and the effect upon the student is bad.

The topical arrangement is shown by Fig. 3.

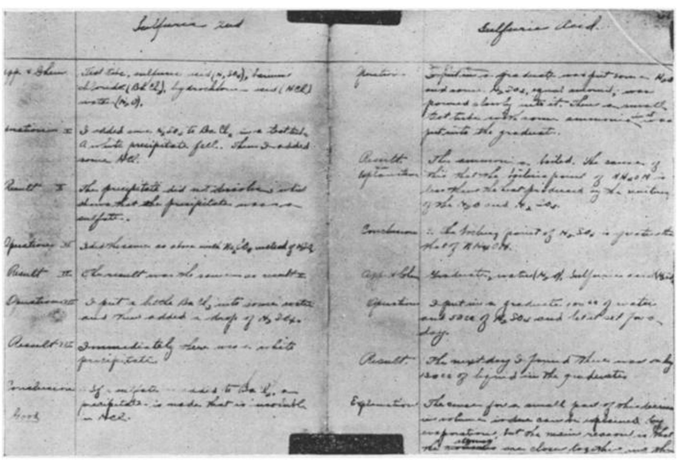


FIG. 3

This is the most common form of notebook. The record is divided into headings: "Apparatus, Operations, Results, and Conclusions," and is similar in some respects to the preceding. Various modifications of this form prevail. If not closely supervised, this method tends to allow the student to drift into the habit of using stereotyped phrases under the different headings. Except in few cases, the books written in this form were not of a high order.

The fourth method is unquestionably the best. It may be called the report method, for the record is written as a clear, simple report. The subdivisions are those which the natural order of the experiment suggests, and are but the paragraphs of ordinary English writing. Part of such a report is shown in Fig. 4.

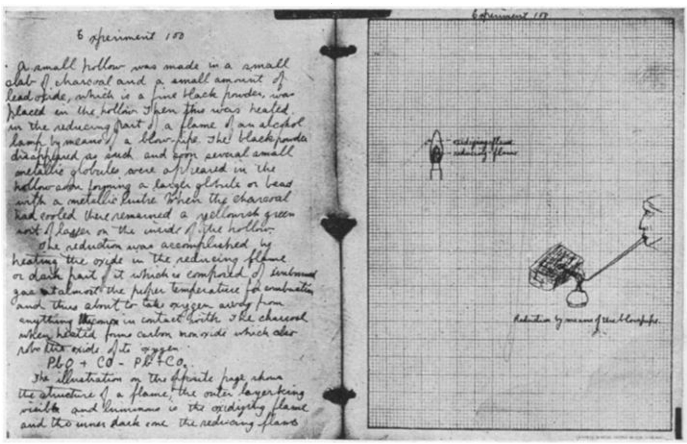


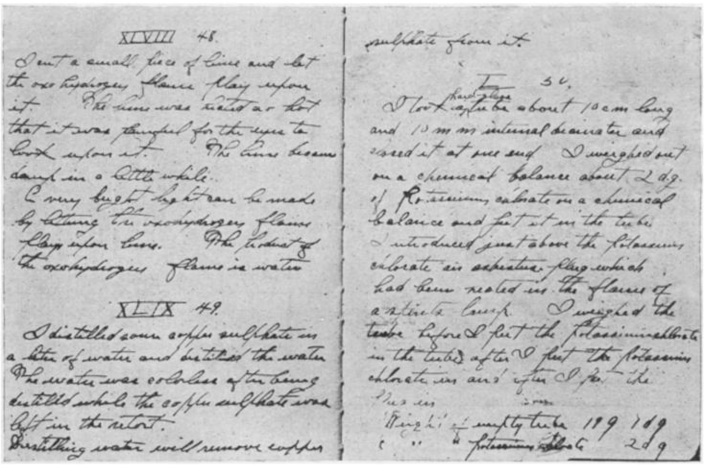
FIG. 4

The advantage of this method lies in the fact that the student is obliged to think connectedly while he writes, and more originality of expression is possible. The emphasis is taken from the operation, and placed upon the clear exposition of the phenomena, and upon the reasoning. Set expressions are avoided, and the teacher is able to render more assistance to the student because his faults stand out more clearly.

IV. THE LITERARY CHARACTER OF THE RECORD

The writing of clear and correct English is a result for which the laboratory notebook affords an excellent training. The teacher

of chemistry and the teacher of English should fully support each other. Drill in the application of a rule may be unpleasant, but with a little care on the part of the teacher the same rule may become an unconscious possession and be used in the writing of an interesting experiment. Teachers of English are often blamed because the students use bad English after their school days are over. It must be confessed, however, that an equal responsibility rests upon the teachers of science who allow the use of expressions which were never learned in the classes in English. If the one teaches the theory of expression, it is the duty of the other to insist upon the correct practice.



XLVIII 48.

I put a small piece of lime and let the oxy hydrogen flame play upon it. The lime was heated so hot that it was painful for the eyes to look upon it. The lime became damp in a little while.

A very bright light can be made by letting the oxyhydrogen flame play upon lime. The product of the oxyhydrogen flame is water

XLIX 49.

I distilled some copper sulphate in a liter of water and distilled the water. The water was colorless after being distilled while the copper sulphate was left in the retort.

Distilling water will remove copper sulphate from it.

L 50.

I took a hard glass tube about 10 cm long and 10 m m internal diameter and sealed it at one end. I weighed out on a chemical balance about 2 g. of Potassium chlorate on a chemical balance and put it in the tube. I introduced just above the potassium chlorate an asbestos plug which had been heated in the flame of a [illegible] lamp. I weighed the tube before I put the potassium chlorate in the tube, after I put the potassium chlorate in and after I [illegible] the [illegible]

Weight of empty tube 19 g
" " potassium chlorate 2 g

FIG. 5

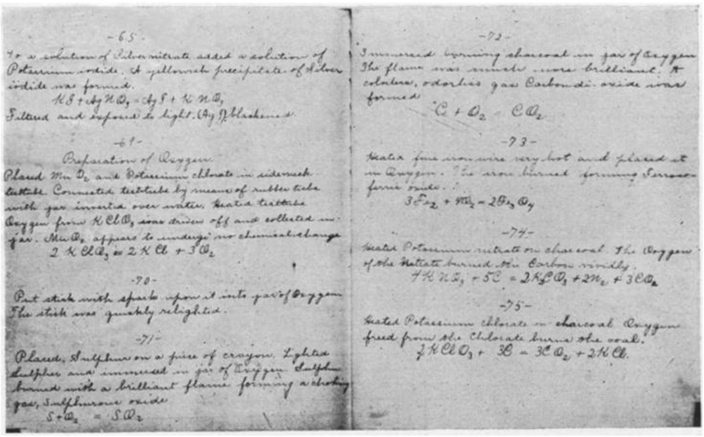
The frequent use of the first person was one of the common characteristics of the notebooks. Fig. 5 illustrates this point.

Students are often urged by the teacher to use that form of expression. Yet it scarcely needs mention that they are thus confirmed in a habit which is avoided in all good writing. The substance, or the observation, may easily be made the subject of the sentence. It may require more effort at first to teach him to use correct expressions, but he will thereby form habits of lasting value instead of those which will need changing later in life. The use of the first person in laboratory records should vigorously be condemned.

Simply bad English was all too common. The teachers evidently spend little time over the literary character of the reports. The fully written record, which has been mentioned, is conducive to the use of good English.

V. THE SCIENTIFIC CHARACTER OF THE RECORD

The subject-matter of the record will not be discussed here, for it is outside the field of this article. The efficiency of the chemical training, however, is unmistakably demonstrated by the scientific character of the record. By that is meant the sort of reasoning



-65-

To a solution of Silver nitrate added a solution of Potassium iodide. A yellowish precipitate of Silver iodide was formed.

$KI + AgNO_3 = AgI + KNO_3$

Filtered and exposed to light. (AgI) blackened.

-69-

Preparation of Oxygen.

Placed MnO_2 and Potassium chlorate in sideneck testtube. Connected testtube by means of rubber tube with jar inverted over water. Heated testtube. Oxygen from $KClO_3$ was driven off and collected in jar. MnO_2 appears to undergo no chemical change.

$2KClO_3 = 2KCl + 3O_2$

-70-

Put stick with spark upon it into jar of Oxygen. The stick was quickly relighted.

-71-

Placed Sulphur on a piece of crayon. Lighted Sulphur and immersed in jar of Oxygen. Sulphur burned with a brilliant flame forming a choking gas, Sulphurous oxide.

$S + O_2 = SO_2$

-72-

Immersed burning charcoal in jar of Oxygen. The flame was made more brilliant. A colorless, odorless gas Carbon di-oxide was formed.

$C + O_2 = CO_2$

-73-

Heated fine iron wire very hot and placed it in Oxygen. The iron burned forming Ferroso-ferric oxide.

$3Fe_2 + 4O_2 = 2Fe_3O_4$

-74-

Heated Potassium nitrate on charcoal. The Oxygen of the Nitrate burned the Carbon vividly.

$4KNO_3 + 5C = 2K_2CO_3 + 2N_2 + 3CO_2$

-75-

Heated Potassium chlorate on charcoal. Oxygen freed from the Chlorate burned the coal.

$2KClO_3 + 3C = 3CO_2 + 2KCl$

FIG. 6

shown, the pertinence of the conclusions, and the general quality of the work.

Fig. 6 illustrates the copying of direction from the laboratory manual—a fault prevalent among the smaller schools.

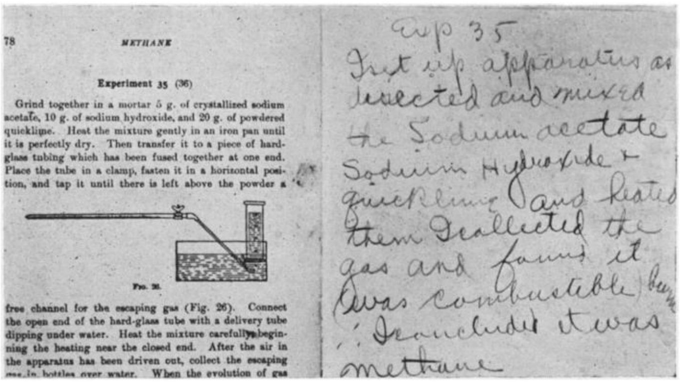
In this case the work was of no value to the student, if not of positive mental injury.

The same figure shows another common defect. The equation is made the aim and conclusion of the experiment, with no semblance of connection with the preceding discussion. The equation has undoubted uses, but should never be written by a beginner, except after a full explanation, if possible after a logical derivation; otherwise wholly erroneous ideas are allowed.

Among all the notebooks reviewed the most recurrent error is illustrated by Fig. 7.

An experiment was performed, an observation made, and a conclusion written out, but no sign of a reason to show how that conclusion was reached from the observation mentioned. Since a "conclusion" was demanded, the student "concluded."

To render conclusions from insufficient data is to develop one of the most vicious habits that can be formed. The student could have been honest with himself and written up a fair exposition of the data and only those deductions which were supported by the


78 METHANE

Experiment 35 (36)

Grind together in a mortar 5 g. of crystallized sodium acetate, 10 g. of sodium hydroxide, and 20 g. of powdered quicklime. Heat the mixture gently in an iron pan until it is perfectly dry. Then transfer it to a piece of hard-glass tubing which has been fused together at one end. Place the tube in a clamp, fasten it in a horizontal position, and tap it until there is left above the powder a

Fig. 26.

free channel for the escaping gas (Fig. 26). Connect the open end of the hard-glass tube with a delivery tube dipping under water. Heat the mixture carefully, beginning the heating near the closed end. After the air in the apparatus has been driven out, collect the escaping gas in bottles over water. When the evolution of gas

Exp 35
Set up apparatus as directed and mixed the Sodium acetate Sodium Hydroxide + quicklime and heated them I collected the gas and found it (was combustible) because ∴ I concluded it was methane

FIG. 7

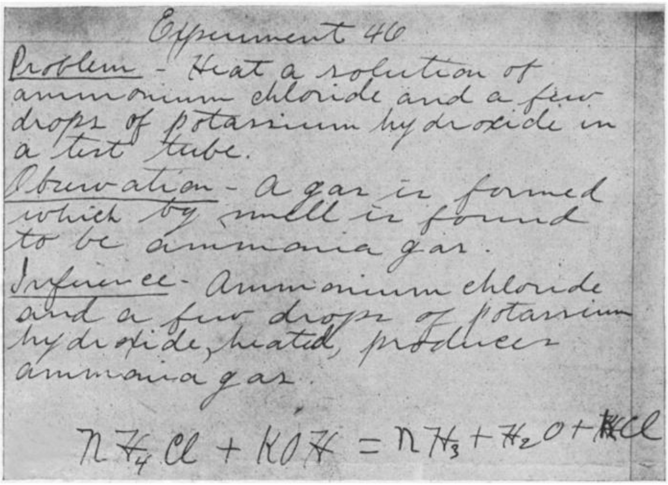
evidence. If it could have been ascertained that the gas was methane only from the teacher or from a reference work, it would have been better to have explained the experiment thus, and so called attention to the existing conditions. Many experiments do not afford the complete data upon which positive statements may be based. It is well that they do not, for thereby a valuable lesson may be learned in rightly judging evidence. Superficial and stereotyped conclusions lead to habits of thinking that render such study of chemistry of more harm than good.

Fig. 8 shows how the directions given may be made the conclusion.

In sharp distinction from the above is the next figure, Fig. 9, and also Fig. 4.

These illustrations confirm the belief that it is quite possible to

obtain satisfactory results, which are well worth the time and energy expended. The figures shown are not ideal in every respect, but



Experiment 46

Problem - Heat a solution of ammonium chloride and a few drops of potassium hydroxide in a test tube.

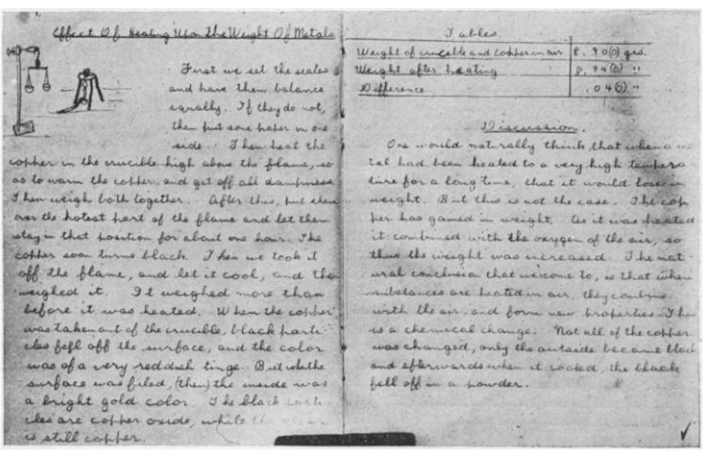
Observation - a gas is formed which by smell is found to be ammonia gas.

Inference - Ammonium chloride and a few drops of potassium hydroxide, heated, produces ammonia gas.

$$NH_4Cl + KOH = NH_3 + H_2O + KCl$$

FIG. 8

they justify the conclusion that good work is promoted by the fully written report.



Effect Of Heating Upon The Weight Of Metals

First we set the scales and have them balance equally. If they do not, then put some paper on one side. Then heat the copper in the crucible high above the flame, so as to warm the copper, and get off all dampness. Then weigh both together. After this, put them over the hottest part of the flame and let them stay in that position for about one hour. The copper soon turns black. Then we took it off the flame, and let it cool, and then weighed it. It weighed more than before it was heated. When the copper was taken out of the crucible, black particles fell off the surface, and the color was of a very reddish tinge. But when the surface was filed, (then) the inside was a bright gold color. The black particles are copper oxide, while [illegible] is still copper.

Tables.

Weight of crucible and copper in air	8.90(0) grs.
Weight after heating	8.94(6) "
Difference	.04(6) "

Discussion.

One would naturally think that when a metal had been heated to a very high temperature for a long time, that it would lose in weight. But this is not the case. The copper has gained in weight. As it was heated it combined with the oxygen of the air, so thus the weight was increased. The natural conclusion that we come to, is that when substances are heated in air, they combine with the air, and form new properties. This is a chemical change. Not all of the copper was changed, only the outside became black and afterwards when it cooled, the black fell off in a powder.

FIG. 9

VI. SPECIAL FEATURES OF THE LABORATORY COURSE

Quantitative experiments have for several years been emphasized by teachers of chemistry. These experiments afford training in measurement and accuracy of observation, and serve to verify the laws which the student would otherwise be obliged to accept as a matter of theory.

The proportion of the schools in which this work is given is an interesting question. In Table III the quantitative and the common

TABLE III

QUANTITATIVE AND PHYSICAL EXPERIMENTS

Subject of Experiment	Percentage of Schools in Which Experiment Was Performed					
	Schools in New York State			Schools Outside New York State		
	Public	Private	Total	Public	Private	Total
1. Distillation	15.4	5.5	12.9	17.0	16.9	16.9
2. Hydrogen equivalent	9.5	33.3	15.7	12.8	25.0	16.9
3. Ionization	3.8	5.5	4.3	4.3	16.7	8.5
4. Law of definite proportions	1.9	5.5	2.9	14.9	20.8	16.9
5. Metal+Oxygen	1.9	11.1	4.3	10.6	4.2	8.4
6. Miscellaneous	5.8	11.1	7.1	10.6	12.5	11.3
Oxygen						
7. Per cent. in air	15.4	27.8	18.6	21.3	12.5	18.3
8. Per cent in $KClO_3$	11.5	22.3	14.3	10.6	8.3	9.9
9. Weight of 1 liter	3.8	11.1	5.7	6.4	25.0	12.7
10. Solubility	13.5	11.1	12.9	19.1	33.3	23.9
Water						
11. Decomposition by electricity	23.1	27.8	24.2	23.4	20.8	22.5
12. H+O by eudiometer	3.8	5.5	4.3	6.4	4.2	5.6
13. H+CuO	5.8	5.5	5.7	12.8	8.3	11.3
14. Water of crystallization	11.5	11.1	11.4	10.6	25.0	14.8

physical experiments are classified so as to give the percentage of the schools which include the experiment in their course. The "distillation" experiment is that of the separation of a salt from water. Under "hydrogen equivalent" is included all forms of that experiment. By "ionization" is meant all those experiments which are intended to illustrate that theory. Under "miscellaneous" are included such experiments as the analysis of a carbonate for carbon dioxide. The "solubility" is the usual form of experiment to determine the approximate solubility of the common salts.

In New York state in all but four—viz., 1, 10, 13, and 14—the private schools give these experiments more generally than do the public schools.

Of the schools outside New York state the private schools exceed the public schools in all but seven of the experiments—viz., 1, 5, 7, 8, 11, 12, and 13.

In all but three—viz., 7, 8, and 11—the schools outside New York state exceed those in the state.

In any event, the number of schools in which this important part of the course is given is small. Probably the figures would be larger if computed on the basis of a single experiment.

TABLE IV

HYDROGEN EQUIVALENT

	Weight Metal	Vol. H. c.c.	Vol. H. Corr.	Weight H.	Equivalent	Percentage Error
ALUMINUM (8.93)						
1	0.06	70.3	64.8	0.0058	10.3	15.3
2	0.06	128.85	111.5841	0.09997935	6.2	30.6
3	0.52	605.0	518.09	0.0466281	11.1	24.3
4	0.08	120.0	106.4	0.00953344	8.39	6.0
5	0.0660	90.0	62.8	0.00742	8.97	0.45
MAGNESIUM (12.1)						
1	0.058	60.6	54.7	0.0049	11.83	2.23
2	0.41	420.0	381.0	0.034	11.98	0.98
3	0.089	84.5	76.8	0.006912	12.87	5.8
4	0.220	248.00	228.8	0.02051	10.75	11.2
5	2.0	217.0	200.184	0.1794	11.16	7.7
6	0.026	25.6	23.29	0.00208	12.5	3.3
7	0.05	56.0	49.79	0.0046	11.5	4.9
8	0.3	370.0	310.25	0.279225	10.7	11.6
SODIUM (22.88)						
1	0.906	462.0	438.3	0.039447	22.967	0.39
2	0.723	385.0	346.6	0.03108	23.26	1.7
ZINC (32.45)						
1	0.0257	102.0	92.5	0.00829	31.0	4.5
2	0.205	78.2	71.9	0.006287	32.69	0.74
3	1.0	680.0	575.1	0.0488	30.71	5.4
4	0.23	92.0	80.8	0.00723	31.8	2.0
5	0.2	72.3	66.3	0.00592	33.8	4.2
6	0.2789	101.0	92.94	0.008377	33.49	3.2
7	0.1	37.0	33.2	....	33.4	2.9
8	0.24	112.0	97.17	0.0087	27.58	15.0

The results which the students obtained with a few of the experiments are shown in the next tables. Table IV gives the results of the hydrogen-equivalent experiment. The first five columns are from the work as found in the notebooks. No attempt was made to correct any errors in that work. In the fifth column, however, it was necessary to recompute the figures, in a few cases, to make them comparable with the other data. Such recomputed data are inclosed in parentheses. The entire sixth column is mine. Inclosed in the parentheses under the name of each metal is the value of the hydrogen equivalent calculated from the atomic weight given in the report of the International Committee on Atomic Weights for 1905.[1]

The table shows that poor work is done, and that good work can be done. The results are evidently the individual work of the student, and show no tendency in any particular school toward any particular results.

From a consideration of columns 3 and 4 a somewhat interesting observation may be made. These columns give the calculations as they were carried out by the students. In only one instance was the metal weighed to four significant figures. In many cases the weight of the metal was expressed in two figures. Yet the calculations in columns 3 and 4 were carried far beyond the limits of experimental error. This is an absurd limit to which to extend calculations. It is better to carry out the computation only to the limit of the accuracy attainable in the experimentation. A training

TABLE V

COMPOSITION OF WATER

$H+CuO$

	Weight O	Weight H_2O	Ratio $H_2:O$	Ratio $O:H_2O$	Percentage Error
			(1:7.94)	(0.888)	
1	0.42	0.48	1:7.0		11.8
2	0.89	1.000	1:8.091		1.9
3	1.0	1.3		(0.770)	13.3
4	20.362	22.905	1:8.007		8.4
5	0.111	0.148		(0.750)	15.6
6	0.910	1.03	1:7.58		4.5

[1] *Journal of the American Chemical Society*, Vol. XXVII (1905), p. 5.

TABLE V—*Continued*

METAL+OXYGEN

MAGNESIUM

	Weight Mg	Weight O	Ratio O:Mg	Percentage Error
			(1:1.52)	
1	0.52	0.33	1:1.57	3.3
2	0.475	0.30	1:1.56	2.6
3	0.29	(0.15)	(1:1.93)	27.0
4	0.165	0.109	1:1.51	0.6
5	1.6	0.87	1:1.84	21.0

PERCENTAGE OF OXYGEN $KClO_3$

	Weight $KClO_3$	Vol. O	Vol. O Corr.	Weight O	Per Cent. O	Percentage Error
					(39.2)	
1	1.52			0.61	40.1	2.3
2	1.75			0.68	39.07	0.33
3	3.67			1.40	38.1	2.8
4	1.62			0.52	(37.1)	5.4
5	1.37			0.544	39.7	1.3
6	0.3365	94.9	84.8	0.1212	35.05	10.6
7	0.25	51.4	47.2	0.067	(26.8)	31.6
8	1.462	420.0	384.78	(.55)	(37.6)	4.1
9	0.2	53.9	49.5	0.08	(40.0)	2.4
10	0.326	95.7	88.905	(.127)	(39.0)	0.51

in judgment is afforded the student if he be taught to choose in each experiment the extent to which he is to carry the divisions and multiplications.

Table V shows the results obtained in some other experiments. The first half of the last part of the table gives the percentage of oxygen obtained by taking the difference in weight between a crucible containing potassium chlorate before and after heating.

The method of the arrangement of the quantitative data in the notebooks may be a matter of some interest. Fig. 10 shows bad arrangement, while Fig. 11 shows excellent arrangement.

VII. CONCLUSION

In conclusion, it may be emphasized that the course in chemistry centers about the laboratory work. The recitation and the experimental lecture have their especial functions to perform, but it is useless to attempt instruction in chemistry without a well-equipped and adequately supervised laboratory.

All things considered, the total amount of time to be spent on laboratory work will depend to a certain extent upon the number of consecutive hours in the laboratory period. If the period is

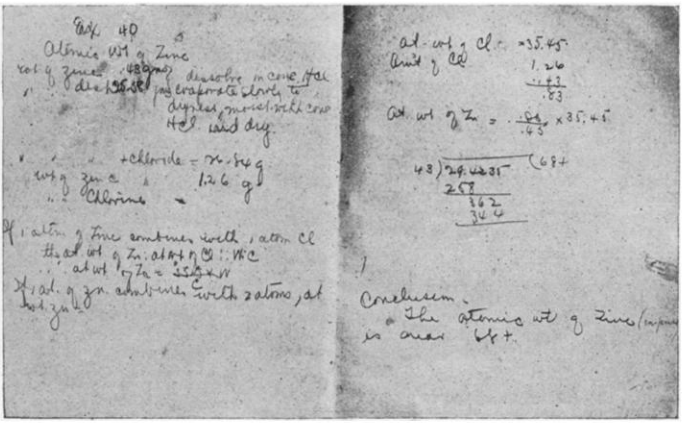
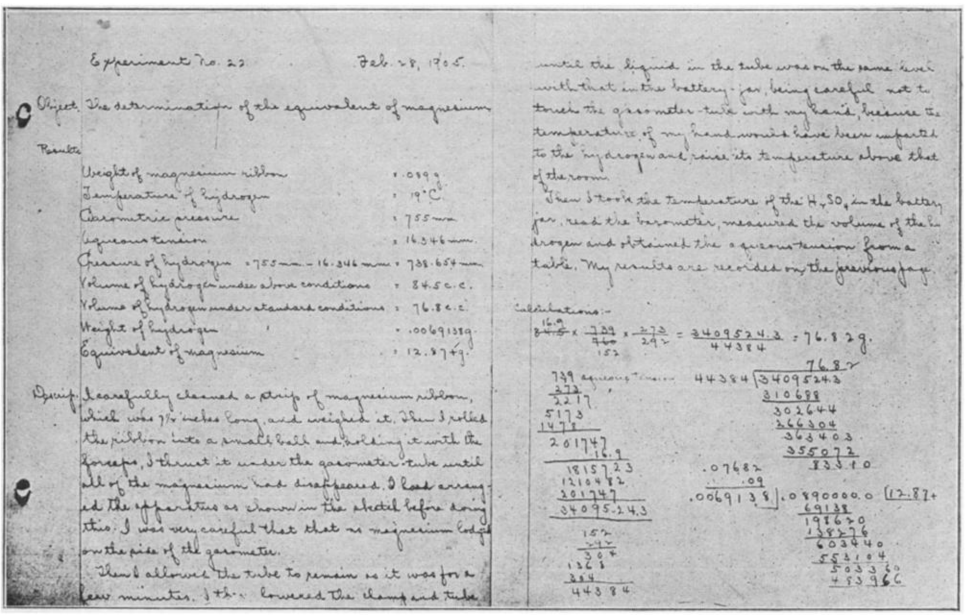

Exp. 40
Atomic Wt of Zinc
Wt of zinc .43 gm. dissolve in conc. HCl, evaporate slowly to dryness, moist with conc. HCl and dry.
+ Chloride = 1.26 g
At. wt of Cl = 35.45
At. wt of Zn = $\frac{.83}{.43}$ × 35.45
Conclusion.
The atomic wt of Zinc is near 68+.

FIG. 10


Experiment No. 22 Feb. 28, 1905.

Object. The determination of the equivalent of magnesium

Results

Weight of magnesium ribbon	= .089 g.
Temperature of hydrogen	= 19°C.
Barometric pressure	= 755 mm.
Aqueous tension	= 16.346 mm.
Pressure of hydrogen = 755 mm. − 16.346 mm.	= 738.654 mm.
Volume of hydrogen under above conditions	= 84.5 c.c.
Volume of hydrogen under standard conditions	= 76.8 c.c.
Weight of hydrogen	= .0069138 g.
Equivalent of magnesium	= 12.87+ g.

Descrip. I carefully cleaned a strip of magnesium ribbon, which was 7½ inches long, and weighed it. Then I rolled the ribbon into a small ball and, holding it with the forceps, I thrust it under the gasometer-tube until all of the magnesium had disappeared. I had arranged the apparatus as shown in the sketch before doing this. I was very careful that that no magnesium lodged on the side of the gasometer.

Then I allowed the tube to remain as it was for a few minutes. I then lowered the clamp and tube until the liquid in the tube was on the same level with that in the battery-jar, being careful not to touch the gasometer-tube with my hand, because the temperature of my hand would have been imparted to the hydrogen and raise its temperature above that of the room.

Then I took the temperature of the H_2SO_4 in the battery jar, read the barometer, measured the volume of the hydrogen and obtained the aqueous tension from a table. My results are recorded on the previous page.

Calculations:–

$\frac{16.9}{84.5} \times \frac{739}{760} \times \frac{273}{292} = \frac{3409524.3}{44384} = 76.82$ g.

FIG. 11

1½ hours in length, then two per week during 36 weeks will accomplish the desired results. Under such an arrangement the total number of hours for the year would be 108. However, if there be more than 1½ consecutive hours in the period, it will be possible to accomplish the same results with fewer total hours.

The character of the notebook record is a matter of vital concern. The best work is done when the student writes a simple but full exposition of the important features of the experiment, with whatever conclusions are to be derived therefrom, and renders it into clear English. It would be advisable to take only rough notes in the laboratory and write the connected report outside, or at least after the entire experiment had been performed.

Emphasis should be laid on the use of good English in the record. The reasons for every conclusion should be fully stated, and the experiment should be interpreted only so far as the conditions and data warrant.

Quantitative experiments are recommended, and the calculations involved should be carried no farther than the limit of accuracy with which the weighings and readings are made.

If the students are well prepared, chemistry can be taught successfully in the high schools. To do so it is necessary to equip the laboratory adequately with desks and apparatus; to allow the students to work in periods of not less than 1½ hours in length; to arrange the teacher's time so that it will be possible for him to prepare experiments and carefully to supervise the laboratory; and for the teacher himself to be well educated and to keep alive to the developments of this progressive science.

The lack of uniformity among the schools is quite remarkable. This may be due to the difference of opinion on the part of the leading educators over the methods to be employed and the time to be given, but more probably the difference is due to the lack of equipment in the schools, which renders chemistry of less importance in the school curriculum than other subjects, and hence less time is allowed to it. Perhaps, also, the school officers do not appreciate the value of chemistry, and so make little or no effort to arrange the school program so as to accommodate a laboratory period of more than 45 minutes in length. Whatever may be the

cause of the conditions, there is need that greater attention be given to chemistry by many schools, if the grade of work is to be high, and there is need that the teachers teach with reference to an ideal standard, rather than merely to pass their pupils over a "minimum requirement" set by some examining board.

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